Fjord Sediment Plumes as Indicators of West Greenland Meltwater Flux

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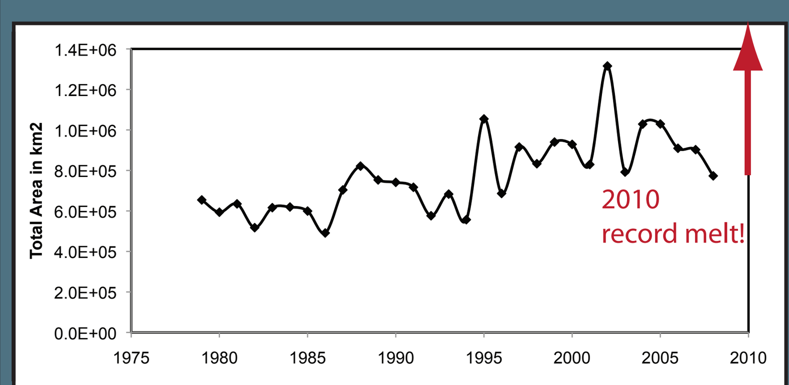
1. "Sink to Source" Approach

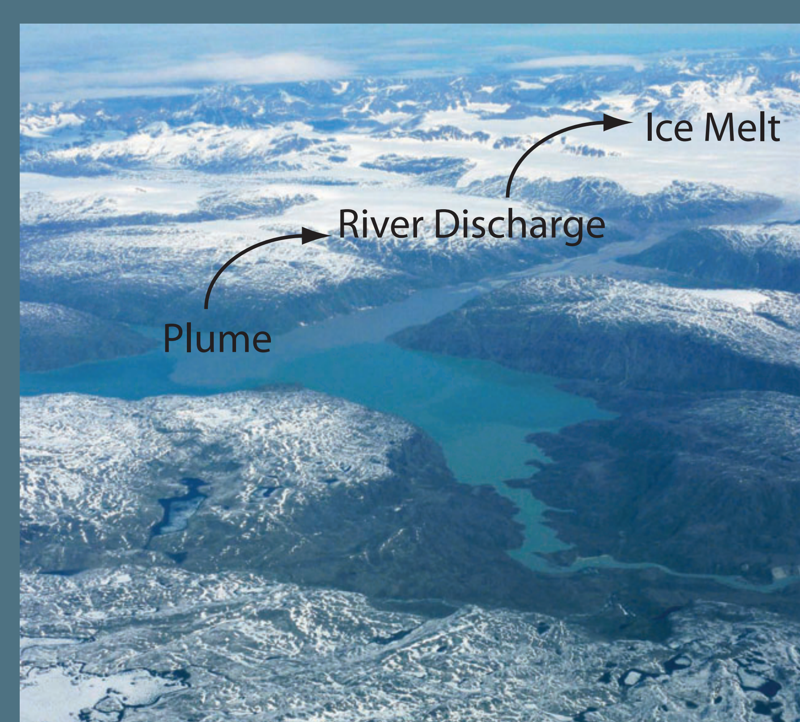
Satelite observations and ice sheet surface mass balance modeling studies indicate that the Greenland Ice Sheet experiences rapid melt. Whereas melt extent on the ice sheet may be observed through satellites, the subsequent meltwater runoff reconstructions carry significant uncertainty. Current reconstructions show that runoff from the Greenland Ice Sheet (GrIS) exceeds 300 km^3/yr, contributing to global sea level rise. This meltwater is the primary driver of river dynamics for the ~320 outlets around the periphery of the ice sheet. Runoff is concentrated between May and August and drains large sediment-rich, freshwater pulses to the fjords and the global ocean with significant implications for ocean circulation. River discharge observations in Greenland are rare, only 4 river systems are now actively monitored.

Our hypothesis: river sediment plume characteristics can be used to assess the timing and volume of freshwater drained to the ocean from the GrIS.



Total Melt on Greenland Ice, 1979-2008

The extent of melt area on the ice sheet is strongly increasing, but subglacial retention is unknown. Question is: does all this surface meltwater ultimately drain to the global ocean?

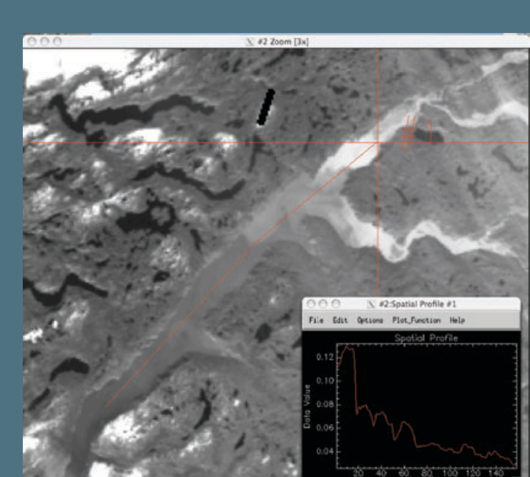


West-Greenland Ice Margin, June 2010

2. Satellite Data Analysis

Buoyant, sediment-laden freshwater plumes are visible on satellite images from the Aqua/Terra MODIS sensor (Band 1, 620-670 nm, 250-m resolution) and thus plume development can be mapped on a daily to weekly basis, depending on cloud cover. Plume lengths are measured from the river mouth based on MODIS Band 1 reflectance > 0.03. MODIS runs from 2001 onwards, so we are building a 10 year record of plume lengths over the melt season.

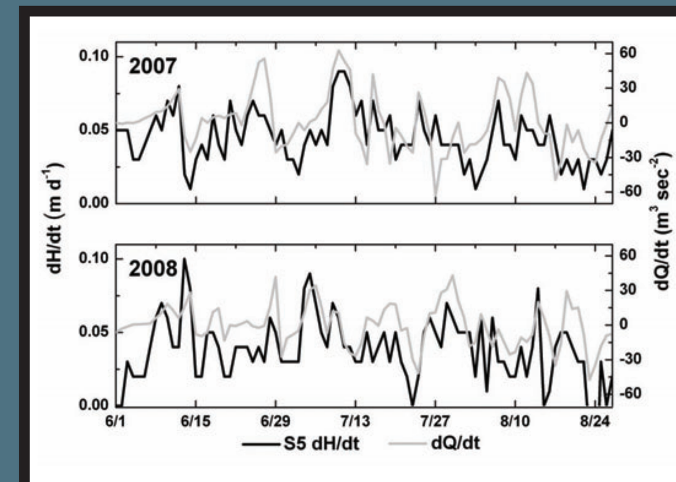
Focus of this poster is on the Watson River and Kangerlussuaq Fjord in West-Greenland.



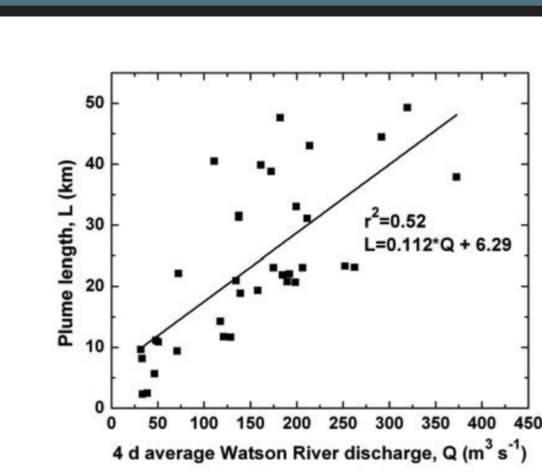
Kangerlussuaq Fjord
Plume Length 35km, June 2010

3. Melt-River-Plume Relationships

Relationships between observed ice ablation, river discharge and plume characteristics has been established for the Greenland Ice Sheet contributing to the Watson river into Kangelussuaq fjord for 2007 and 2008. Automatic weather station S5 (490m a.s.l.) measures ablation with a sonic ranger. Daily stage is measured at the Watson River bridge.



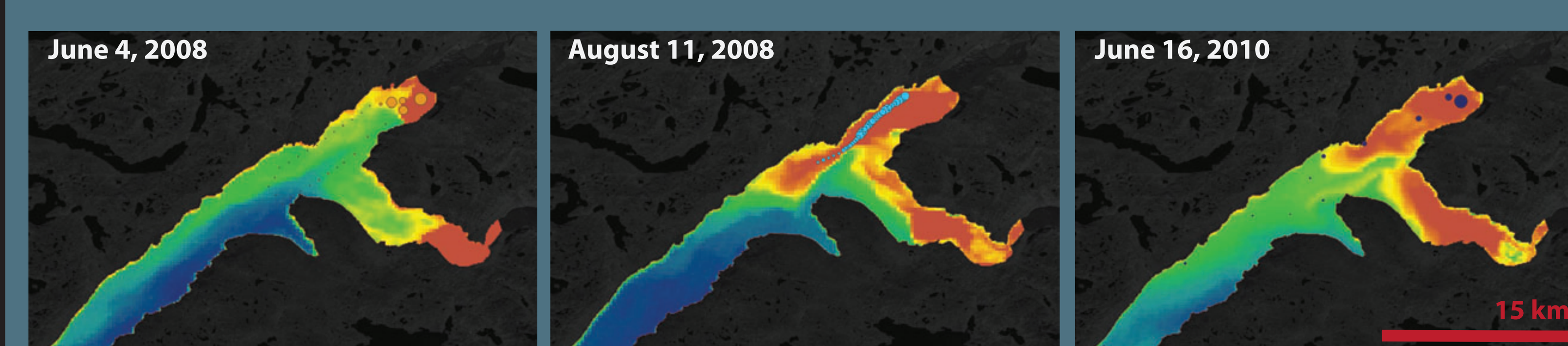
River discharge responds closely to ablation changes observed on the GrIS



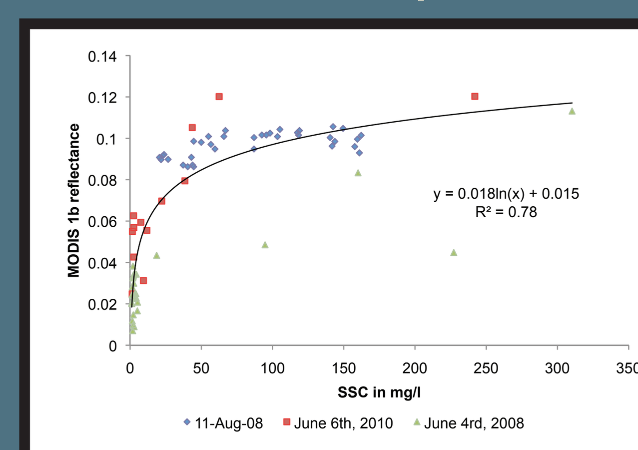
Plume length correlates with observed riverdischarge

4. Plume Characteristics

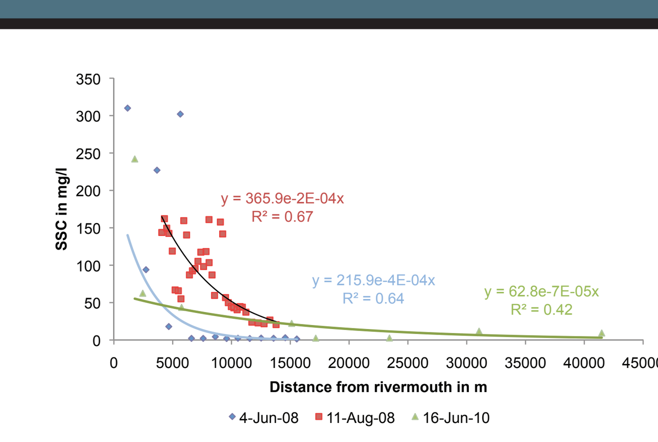
Steady-state plume dynamics are described with an simplified 2D advection-diffusion equation, sediment concentration at any x,y coordinate in the plume becomes a function of the inital river mouth velocity and waterdepth (which we want to resolve for) and of the sediment inventory. CTD cast constrain plume depths (6-8 m), and suspended sediment load samples at different distances constrain inventory rates.



MODIS reflectance patterns (band 1, 620-670 nm), with Suspended Sediment Concentration, from surface water samples.



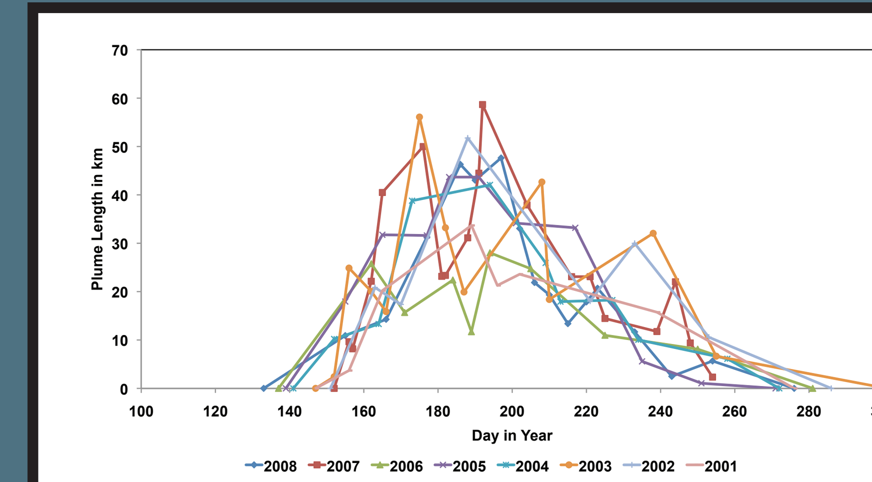
Transfer function between reflectance and SSC for 3 sample days.



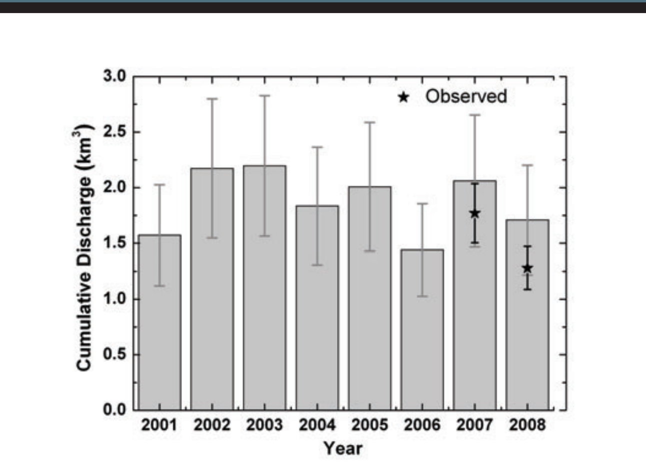
SSC settling curves for 3 sample days.

5. First Estimates of Ice Melt

We calculated sediment plume lengths for 2000-2008 for all available, cloud-free MODIS images. Since plume length proved to be a significant function of river discharge in our study area, we subsequently reconstructed the cumulative discharge from Watson River for each melt season 2001–08.



Plume lengths from MODIS 2001-2008



Annual discharge for 2001-2008. Overestimations are 15% and 29%.

6. Conclusions & Next Steps

1) Ablation onset and cessation at the Kangerlussuaq weather station (AWS) S5 (490 m asl, 6 km from the ice margin) is positively correlated with the sediment plume formation and cessation (r2=0.88, r2=0.93, 2003–2008).
2) Plume length is mapped using reflectance of MODIS. Sediment plume length variability throughout the 2007 and 2008 melt seasons is correlated (r2=0.64, n=37, p<0.01) with the 4-day mean Watson River discharge.
3) The plume length variability is then derived to reconstruct annual cumulative Watson River discharge from 2001–2008. Reconstructed values are within ~12% of measured cumulative discharge values in 2007 and 2008. The fluctuations in the 7 year reconstructed record match modeled runoff for the entire ice sheet.

We plan to develop an Inverse Model: we ultimately want to use the reflectance patterns of the MODIS data to make predictions of forcing river discharge. The PLUME model wil be inverted to generate discharge time series, based on plume centerline settling curves.

7. Key References

McGrath, D., K. Steffen, I. Overeem, S. H. Mernild, B. Hasholt, and M. van den Broeke 2010. Sediment Plumes in Kangerlussuaq, West Greenland, as a proxy for runoff from the Greenland Ice Sheet. Journal of Glaciology, 56(199): 813–821.

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